THE PONDS AND LAGOONS OF HORN AND PETIT BOIS ISLANDS, MISSISSIPPI, GULF ISLANDS NATIONAL SEASHORE: THEIR PHYSICAL SIZE, LITERATURE REVIEW AND RECOMMENDATIONS FOR FUTURE RESEARCH

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Abstract

The physical nature and natural resources of the ponds and lagoons on Horn and Petit Bois Islands, Gulf Islands National Seashore, Mississippi, have received little attention in the past and are consequently relatively unknown. A survey was conducted to assess the physical size of each body of water on both islands and a literature review was also carried out. Petit Bois Island contains 17 ponds and lagoons that compose a total of 46.26 acres (18.71 hectares), or 3.2 % of the island mass. Horn Island has 63 ponds and lagoons covering a total of 191.58 acres (77.53 hectares), or 5.8 % of the island. Since 1965-66, on Horn Island 17 ponds and lagoons have remained relatively stable. In addition, on Horn Island 12 water bodies evolved into 5 discrete ponds, 19 water bodies ceased to exist, and 38 new bodies originated and evolved into ponds. Newly evolved ponds on Horn Island range in size from 0.08 acres (0.03 hectares) to 1.25 acres (0.51 hectares). The average size of the new ponds is 0.39 acres (0.16 hectares). The ponds and lagoons of both Horn and Petit Bois Islands are concentrated on the eastern, geologically oldest, and most stable portions of the islands. All ponds and lagoons consist of brackish water. The literature pertinent to the vegetation, fin fish, and oyster populations of selected ponds and lagoons is reviewed. The study identified some information gaps that need to be addressed in order to assist the National Park Service in managing these unique resources. Recommendations for future research are made.

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Introduction

Petit Bois and Horn Islands are 1454.6 acre (588.7 hectare) and 3309.0 acre (1339.2 hectare) wilderness islands, respectively, located from 8 miles (13 km) to 12 miles (19 km) off the coast of Mississippi (Fig. 1). The islands are part of Gulf Islands National Seashore, authorized in 1971 (U.S. Government, 1967) and administered by the National Park Service, U. S. Department of the Interior.

The physical, biological, and limnological features of the ponds and lagoons found on these two islands have received little attention in the past and are consequently relatively unknown. Eleuterius (1979), as part of an intensive phytosociological study of the flora of Horn and Petit Bois Islands, discussed the lagoons and ponds only with respect to their flora. Franks (1970) studied the fish populations of all the existing lagoons and ponds of Horn Island in 1965 and 1966. The following studies, supervised or currently supervised by Cake (personal communication) of the Gulf Coast Research Laboratory, Ocean Springs, Mississippi, have been performed on the oyster populations of lagoons 7 and 28 (see Fig. 3) on Horn Island. McGraw (1980) evaluated the potential of using hatchery-reared seed oysters for stocking and mariculture operations in Mississippi Sound, including lagoon 28. She also compiled information on various aspects of oyster biology. Hase (1982) studied the potential for improving oyster production in lagoon 28. At present, Richard Sherrard, under Cake, is performing a study of the infauna of lagoon 28. These represent the only investigations, to our knowledge, of the resources of the ponds and lagoons of Horn and Petit Bois Islands.

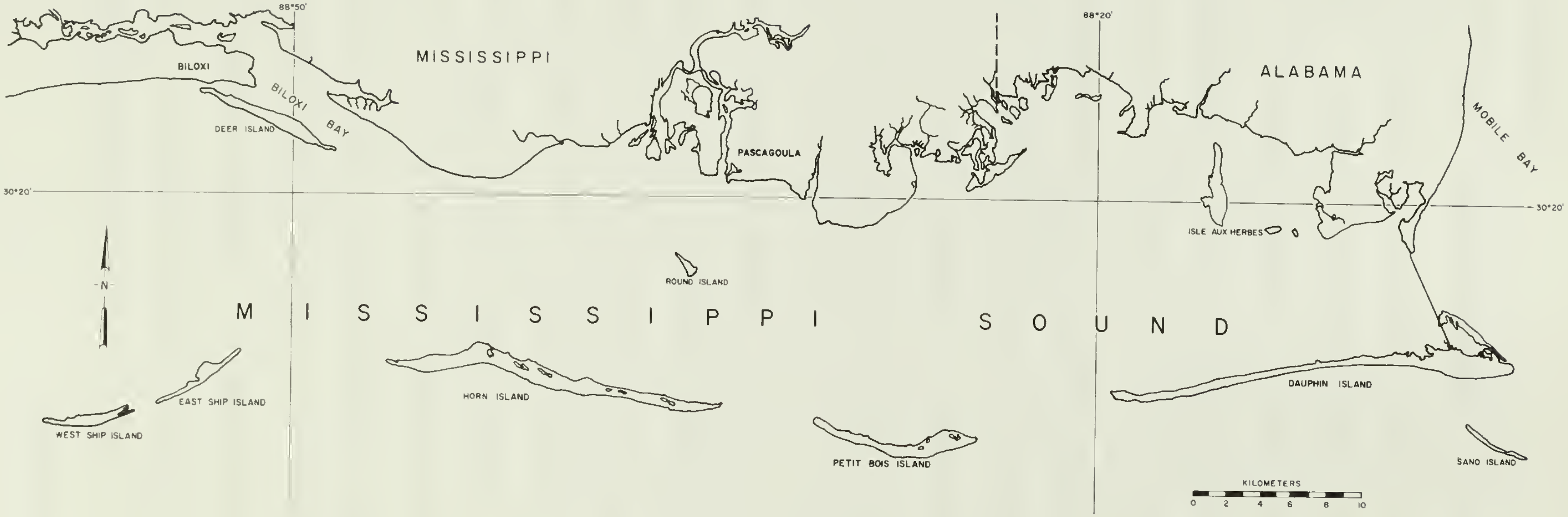

Fig. 1. Location map of Horn and Petit Bois Islands, Gulf Islands National Seashore, Mississippi.

The origins of the various water bodies on Horn and Petit Bois Islands are unclear. Franks (1970) believed that their creation is storm related. Priddy (cited in Franks, 1970, p. 9) stated that the lagoons "were originally huge tide-pools created during severe storm conditions. They are usually situated closer to the Sound because of the progressive growth of the island shoreline Gulfward." Eleuterius (1979) theorized that most of the ponds on the islands probably evolved from lagoons which were isolated from Mississippi Sound waters. Franks (1970) felt that the smaller ponds, which he termed pools, are formed in low areas where rainfall collects, and from storm related events.

Our study was performed to assess the physical size of each body of water located on Horn and Petit Bois Islands, to review prior studies of the lagoons and ponds, and to identify programs of research that would fill in many of the gaps in our knowledge and assist the National Park Service in managing these resources.

Materials and Methods

For the purpose of this study the following definitions of a pond and a lagoon have been derived:

> A pond is defined as a confined body of fresh water or brackish water with no tidally generated freshwater-saltwater exchange.
>
> A lagoon is defined as a confined body of brackish or saline water having restricted inlets to the sea, generally tidally influenced, with little freshwater inflow.

There are numerous water bodies (for example: 14, 61, 63 on Horn Island, and 14 on Petit Bois Island) which are infrequently connected to Mississippi Sound due to the deposition of sand across their outlets. These are classified as ponds, but their water characteristics are generally brackish during most of the year.

Using vegetation maps of Petit Bois and Horn Islands prepared by Eleuterius (1979), pond and lagoon acreages were determined. Each identified water body was designated from west to east, with 17 and 63 ponds and lagoons found on Petit Bois and Horn Islands, respectively. A Dell Foster Digital Planimeter was employed to calculate the areal values. The 17 and 63 ponds and lagoons of Petit Bois and Horn Islands, respectively, are identified in Figures 2 and 3 found in the rear jacket pocket of this report.

Results and Discussion

The calculated acreage for each pond and lagoon is shown comparatively in Tables 1 and 2. Petit Bois Island (Table 1) has 17 ponds and lagoons that compose a total of 46.26 acres (18.71 hectares), or 3.2 percent of the island mass. Horn Island (Table 2) has 63 ponds and lagoons covering a total of 191.58 acres (77.53 hectares), or 5.8 percent of the island. In 1965 and 1966, Franks (1970) identified 49 discrete lagoons, ponds, pools, and ditches on Horn Island. We observe 63 ponds and lagoons based on the map of Eleuterius (1979) and our ground surveys of 1980 and 1981. Seventeen of the ponds and lagoons surveyed by the Coastal Field Research Laboratory (CFRL) are equivalent to 17 of Franks' (1970) water bodies, indicating that these bodies have remained relatively stable during the last 15-16 years (see Table 3). In addition, five ponds and lagoons surveyed by CFRL correspond to 12 of Franks' (1970) water bodies. In Table 3, for example, CFRL pond no. 24 includes Franks' lagoon 23 and ponds 24 and 25. Thus, five of the ponds and lagoons surveyed by Franks (1970) in 1965-66 have expanded in areal extent to encompass other water bodies at the present time. In the interval since 1965-66, only one pond decreased in areal extent. Franks' pond 37 (see Table 3) evolved into three ponds, CFRL nos. 53, 54 and 58. Since 1965-66, 19 of Franks' (1970) water bodies have ceased to exist, but 38 new bodies have originated and evolved into ponds. There was therefore a net increase of 19 ponds on Horn Island since 1965-66. These newly evolved ponds range in size from CFRL pond no. 3 (the smallest), consisting of 0.08 acre (0.03 hectare), to CFRL pond no. 21 (the largest), consisting of 1.25 acres

Table 1. Physical size of the ponds (P) and lagoons (L) of Petit Bois Island (see Fig. 2 for locations). CFRL: Coastal Field Research Laboratory.

CFRL Identification Number	Size		Lagoon or Pond
	Acres	Hectares	
1	0.79	0.32	P
2	1.69	0.68	P
3	6.55	2.65	L
4	0.25	0.10	P
5	1.22	0.49	P
6	0.35	0.14	P
7	4.02	1.63	L
8	3.48	1.41	P
9	0.20	0.08	P
10	0.17	0.07	P
11	0.23	0.09	P
12	0.22	0.09	P
13	5.89	2.38	P
14	18.04	7.30	P
15	0.46	0.19	P
16	0.69	0.28	P
17	2.01	0.81	P
Totals	46.26	18.71	

Table 2. Physical size of the ponds (P) and lagoons (L) of Horn Island (see Fig. 3 for locations). CFRL: Coastal Field Research Laboratory.

CFRL Identification Number	Size		Lagoon or Pond	CFRL Identification Number	Size		Lagoon or Pond
	Acres	Hectares			Acres	Hectares	
1	0.48	0.19	P	32	0.16	0.06	P
2	0.73	0.30	L	33	0.28	0.11	P
3	0.08	0.03	P	34	0.11	0.04	P
4	0.44	0.18	P	35	0.14	0.06	P
5	0.37	0.15	P	36	0.16	0.06	P
6	0.60	0.24	P	37	0.09	0.04	P
7	53.63	21.70	L	38	2.75	1.11	P
8	0.83	0.34	P	39	0.20	0.08	P
9	0.44	0.18	P	40	4.12	1.67	P
10	0.95	0.38	P	41	6.17	2.50	L
11	0.47	0.19	P	42	1.76	0.71	P
12	1.05	0.42	P	43	8.26	3.34	P
13	1.02	0.41	P	44	0.54	0.22	P
14	0.29	0.12	P	45	0.34	0.14	P
15	1.28	0.52	P	46	0.23	0.09	P
16	0.33	0.13	P	47	0.11	0.04	P
17	0.39	0.16	P	48	0.39	0.16	P
18	24.91	10.08	P	49	0.40	0.16	P
19	5.87	2.38	P	50	1.20	0.49	P
20	8.49	3.44	P	51	9.16	3.71	P
21	1.25	0.51	P	52	1.15	0.47	P
22	0.12	0.05	P	53	0.83	0.34	P
23	0.57	0.23	P	54	0.81	0.33	P
24	2.52	1.02	P	55	0.25	0.10	P
25	1.60	0.65	P	56	0.71	0.29	P
26	0.48	0.19	P	57	0.11	0.04	P
27	0.47	0.19	P	58	0.09	0.04	P
28	28.54	11.55	L	59	0.12	0.05	P
29	0.18	0.07	P	60	0.41	0.17	P
30	0.21	0.08	P	61	10.51	4.25	P
31	0.10	0.04	P	62	0.19	0.08	P
				63	1.14	0.46	P
				Totals	191.58	77.53	

Table 3. Compiled data for the ponds and lagoons of Horn Island based on the study by Franks (1970). The first two columns show Coastal Field Research Laboratory (CFRL) pond and lagoon identification numbers and those of Franks, respectively. Codes and notes are listed below.

CFRL ID#	Franks ID#	Type	Maximum Depth Feet	Maximum Depth Meters	Bottom Composition	Vegetation Submerged	Vegetation Shore	Salinity (ppt)	Number of Fish Species
1	2	D	3.0	0.9	M,S	R	J,SP,SA	5.0-9.1	11
2	6	D	3.0	0.9	S	R,E	J	5.5	7
6	8	P	4.0	1.2	TM	R	J,SP,T,U	3.9	3
7	10	T	6.0	1.8	M,S	R,E	J,SP,SC,A,U	23.0-29.9	40
13	11	P	5.0	1.5	TM	N	J,SP,C	5.1	9
15	12	P	4.0	1.2	M,S	N	J,SP	7.2	10
18	18	P	6.0	1.8	M,S	SR,E	SP	7.0-13.3	22
19	17	L	5.0	1.5	M,S	R	SP	7.5	13
20	14	P	4.0	1.2	M,S	R	J,SP	9.3	8
24	19	P	1.5	0.5	M,S	R	SP	15.1	7
⊥	20	P	2.0	0.6	M,S	R	SP	15.1	5
25	21	P	2.0	0.6	S	R	SP	14.3	4
28	23	L	4.0	1.2	M,S	R,E	J,SP,SC,A	23.0-27.0	17
│	24	P	1.5	0.5	S,SM	N	J,SP	4.6	5
⊥	25	P	1.5	0.5	S,SM	N	C	4.8	4
38	28	P	3.0	0.9	M,S	R	J,SP	3.0	5
40	30	P	2.0	0.6	M,S	R	J,SP	2.6	4
⊥	31	P	1.5	0.5	M,S	R	J,SP	2.1	4
41	29	L	4.0	1.2	M,S	SR,E	J,SP	22.7	13
42	32	P	0.8	0.2	M,S	N	J,SP	11.3	4
43	33	P	6.5	2.0	S,SM	SR,E	J,SP,SA	0.6	9
51	34	P	2.5	0.8	S,SM	SR	J,SA,SP	19.0	8
⊥	35	P	2.5	0.8	S,SM	SR	J,SP,SA	18.3	9
52	36	P	3.0	0.9	S,SM	N	J,SP	10.8	6
53	37	P	3.5	1.1	S,SM	N	J,SP	11.0	7
54	│	│	│	│	│	│	│	│	│
58	⊥	⊥	⊥	⊥	⊥	⊥	⊥	⊥	⊥
61	38	P	6.5	2.0	S,SM	R	J,SP	17.1-18.0	30
62	39	P	1.0	0.3	S,SM	N	J,SP,CE	21.5	6
63	40	P	1.0	0.3	S,SM	N	J,SP,CE	27.1	5
│	41	P	2.0	0.6	S,SM	N	J,SP,CE	27.1	3
⊥	44	P	2.0	0.6	S,SM	N	J,SP,CE	27.0	4

Codes and Notes to Table 3

TYPE

T	Tidal lagoon permanently connected with Mississippi Sound
L	Lagoons and ponds which are usually connected with Mississippi Sound during high tide by means of tidal channels
P	Lagoons and ponds which are isolated except during abnormally high tides
D	Ditches

BOTTOM COMPOSITION

M	Mud
S	Sand
TM	Thick, black mud
SM	Soft, black mud

VEGETATION (listed in descending order of dominance)

Submerged

N	None
R	Patches of *Rupia*
SR	Strands of *Rupia*
E	*Ectocarpus*

Shore

J	*Juncus*
SP	*Spartina*
SC	*Scirpus*
A	*Andropogon*
U	Strands of *Uniola*
C	*Cladium*
SA	*Sagittaria*
CE	Clumps of *Ceratiola*
T	*Typha*

SALINITY: Generally based on single sample except where a range of salinities are noted.

(0.51 hectare). The average size of the 38 new ponds is 0.39 acre (0.16 hectare), and only three (CFRL nos. 12, 21, and 50) are greater than one acre (0.41 hectare).

It thus appears that the pond systems on Horn Island are expanding, not only in terms of newly evolved ponds, but through the inclusion of two or more existing ponds into larger solitary ponds. The reasons for these expansions are not clear at this time; however, since 1966 two major hurricanes have impacted Horn Island: Hurricanes Camille in 1969 and Frederic in 1979. The storm surge and overwash processes associated with these storms may be partly responsible.

The largest water bodies on Petit Bois and Horn Islands are pond no. 14 (18.04 acres, 7.30 hectares) and lagoon no. 7 (53.63 acres, 21.70 hectares), respectively. The smallest water bodies on Petit Bois and Horn Islands, both ephemeral ponds, are no. 10 (0.17 acres, 0.07 hectares) and no. 3 (0.08 acres, 0.03 hectares), respectively. Petit Bois and Horn Islands have two and four tidal lagoons, respectively (see Table 4).

The ponds and lagoons on Petit Bois Island (Fig. 2) are concentrated on the eastern one-third of the island. This is geologically the oldest (Shabica and others, 1978) and most stable part of the island. Relict dune ridges and the highest dunes on the island are found here, around and within the small forest from which the island derives its name. Situated in the low areas between or along these dune ridges are four discrete pond systems: ponds 8, 14 and 17 comprise the first three. The fourth system consists of ponds 12, 13, 15, and 16. Although not connected, these four ponds are found within the same dune ridge system. It is possible that in the past, these four constituted a single pond or lagoon. Ponds and lagoons are relatively absent from the western portion

Table 4. Tidal and non-tidal lagoons and ponds on Horn and Petit Bois Islands based on our inspection in June 1981.

	Horn Island				Petit Bois Island			
	Number	% of Total	Acres (Hectares)	% of Total	Number	% of Total	Acres (Hectares)	% of Total
Tidal	4	6.8	89.07 (36.05)	46.49	2	11.8	10.57 (4.28)	22.85
Non-tidal	59	93.2	102.51 (41.49)	53.51	15	88.2	35.69 (14.44)	77.15

of the island. This is probably related to the low, flat topography which characterizes this area and the absence of well defined dune ridge systems. An excellent review of sand dunes and dune systems is found in Cooper (1958) to which reference should be made for further information.

Like those on Petit Bois Island, the ponds and lagoons on Horn Island (Fig. 3) also occur on its eastern half and are situated in the low areas between or along both Recent and relict dune ridges. Horn Island contains 14 discrete systems which include single ponds 19, 38, 40, 61, and 63, and lagoon 28. The remaining eight systems, each consisting of two or more water bodies, include: ponds 8, 13, 14; 9 through 11; 16 and 18; 20 through 23; 31 through 36; lagoon 41 and ponds 42, 43; ponds 49 through 51; and ponds 52 through 59. Although not connected, each of these composites is found within a discrete dune ridge system.

The presence of the ponds and lagoons within the dune ridge systems of both islands suggests to us that island physiography is the controlling factor in the origin and evolution of the ponds and lagoons. Obviously, water from storm surges, overwash, and rainfall are required to fill these low areas. But it is primarily the ridge systems, among others, that determine where the surge and overwash will penetrate, scour the island, and allow water to accumulate. The existence of insular dune ridge systems similar to those on Horn and Petit Bois Islands is a function of sand supply, vegetation, and prevailing wind climate. Many of the interior ridges observed on Horn and Petit Bois reflect historical shoreline orientations and were once primary dune ridges separating the active beach from the islands' lower interior. These ridges were thus once part of the active progradational and migratory aspects of the islands (see Shabica and others, 1978 for a discussion of island migration). Once isolated from the active beach, the lower, interdune swales provided the necessary topographic low areas for scouring by overwash, rain water and washover accumulation, or tidal innundation. Many of the pond and lagoon water surfaces are located below or at the level of the Mississippi Sound and Gulf of Mexico waters. However, Eleuterius (1979) described several ponds which had bottoms located at elevations above the surrounding Sound and Gulf waters.

On Petit Bois Island, 47.1 percent of the ponds and lagoons are greater than one acre (0.41 hectare) and comprise 92.7 percent of the total water area. On Horn Island, 33.3 percent of the ponds and lagoons are greater than one acre (0.41 hectare) and comprise 92.1 percent of the total water area on the island.

Eleuterius (1979) noted that the water depths of the ponds and lagoons of Horn and Petit Bois Islands were shallow and generally 1-3 ft (0.3-0.9 m) deep, but up to 5 ft (1.5 m) in some places. He also observed that most of the ponds and lagoons had muddy bottoms, although some freshwater ponds had sandy bottoms. Sand also predominates at the inlets to the lagoons. The water in most of the ponds Eleuterius (1979) investigated was turbid and contained no aquatic plants in the deep areas. A few aquatic plants, of which Chara sp. is the most abundant, were found in the shallow fringing parts of the ponds. In addition, he found that cattails (Typha) form a narrow band along the freshwater ponds. The brackish plant Ruppia maritima was found to occur in the waterways of the lagoons and less often on the bottoms of the more central, "open water" areas (Eleuterius, 1979). Relatively pure stands of the marsh grass Juncus *roemerianus* were found around lagoon inlets where the salinity is relatively high. *Spartina alterniflora* formed a narrow fringe along the water's edges of the lagoons, with *S. patens* and *Panicum repens* occurring in the higher marsh areas (Eleuterius, 1979).

Franks (1970) studied the fish populations of the water bodies on Horn Island during 1965 and 1966. He identified 49 lagoons, ponds, pools, and ditches. The following definitions are from Franks (1970): " . . . a lagoon is considered to be a large body of water several feet in depth . . . and may support submerged aquatics." A lagoon is generally connected to Mississippi Sound during high tides. "A pond shall be defined as a small to medium sized, relatively shallow, murky body of water which may be adjacent or distal to any of the lagoons. Ponds may or may not support vegetation." Ponds are generally isolated except during exceptionally high tides. "Pools . . . the smallest bodies of water . . clear and shallow. Heavy rainfall is responsible for the formation of some pools. The pools may have originated during storms . . . Drainage ditches are either former drainage channels for previously existing inland bodies of water or passages through which hurricane flood waters have flowed" (Franks, 1970). During his study, 28,587 specimens of fish were collected, including 69 species representing 58 genera and 35 families. A summary of the overall results of Franks' study is found in Table 3. The ponds, lagoons, pools, and ditches were populated by both marine and brackish water fishes. No true freshwater fish were obtained, although several euryhaline species were collected from freshwater bodies. At the time of our survey, there were no known freshwater bodies on either Horn or Petit Bois Islands. Five species, *Cyprinodon variegatus*

(Southern sheepshead killifish), Fundulus similis (Longnose killifish), Gambusia affinis (Mosquito fish), Menidia beryllina (Tidewater silverside), and Poecilia latipinna (Sailfin molly), accounted for 86.0 percent of the total catch. Poecilia latipinna was the most abundant species, representing 23.7 percent of the total fish collected. Six species of killifish and two species of poeciliids were considered by Franks (1970) to be residents of the Horn Island water bodies since they are capable of completing their life histories in these areas. In addition, these fish have established resident breeding populations and contribute most (77.1 percent) to the permanent occupancy of the inland waters of Horn Island.

At the time Franks (1970) performed his study of Horn Island, the discrete ponds that we noted as 53, 54, 58 in 1981 were a single pond, number 37 (Franks' identification number). In five cases where we noted only a single lagoon or pond, Franks noted two or more. For example (see Table 3), CFRL lagoon 28 was Franks' lagoon 23, and ponds 24 and 25. Ditch number 2 (Franks) had become a lagoon by the time of our evaluation (CFRL number 2, Horn). The depths of the water bodies that Franks evaluated ranged from less than one foot (0.3 m) to 6.5 ft (2.0 m) and are similar to those depths that Eleuterius (1979) noted. The bottom compositions (Table 3) of all water bodies generally consisted of predominantly mud or sand, and sand or soft, black (anaerobic) muds (Franks, 1970). Rupia and Ectocarpus were the only submerged vegetation observed by Franks (1970). However, Eleuterius (1979) did not observe Ectocarpus during his investigations. Shoreline vegetation generally consisted of Juncus and Spartina with occasional strands of Scirpus, Sagittaria and Ceratiola (Franks, 1970).

Salinities of all the water bodies ranged from a low of 0.6 to a high of 29.9 parts per thousand (ppt) (Franks, 1970). The highest salinities were consistently observed in those lagoons with continuous or periodic connections to Mississippi Sound. Several ponds, however, had salinities in excess of 15 ppt, attesting to the effects of storm waters or exceptionally high tides. Mississippi Sound and Gulf of Mexico waters have inundated the entire land masses of Horn and Petit Bois Islands (except for some of the higher dunes and dune ridges) during periods of severe tropical storms such as Hurricanes Camille (1969) and Frederic (1979). Thus the lagoons and ponds have been flushed with salt water from overwash and the associated storm surge. During Hurricane Frederic at least the central portion of Horn Island (probably most of the island) near lagoon 28 was under 4 ft (1.2 m) of water from Mississippi Sound (P. Toops, personal communication). In addition, our investigations, based on the height of the drift line in shrubs, showed that ponds 13 and 14 on Petit Bois Island were under from 4 ft (1.2 m) to 6 ft (1.8 m) of water from the Gulf of Mexico. Any freshwater body, so affected, would become confined bodies of salt water until percolation, leaching, and rainfall remove the salts. It is highly probable that many of the fish species that occur in the confined ponds and pools of Horn and Petit Bois Islands are carried to these areas during such events. Some ponds, such as CFRL 48 and 61 on Horn Island and CFRL 1 and 2 on Petit Bois Island, are periodically overwashed during even moderate storms. These ponds are thus brackish most of the year, especially during extended periods of drought.

The ponds and lagoons derive their freshwater solely from rainfall. During periods of extended drought it is not uncommon for many of the smaller ponds (less than 1 acre, 0.41 hectare, in size) to dry up completely. The lagoons are generally equivalent in salinity to Mississippi Sound, except during periods of high rainfall when salinities as low as one to two parts per thousand are observed.

Mississippi Sound salinities, based on averages of four and five year monthly averages (Gulf Coast Research Laboratory, 1980), range from a low of 7 ppt in April to a high of 21.3 ppt in November. Eleuterius and Beaugez (1979) compiled, by season, mean sea surface temperatures and salinities for Mississippi Sound. These values are shown in Table 5 for the north shores (Mississippi Sound) of both Horn and Petit Bois Islands. The highest average salinities in Mississippi Sound (18.1-21.3 ppt) occur from August through November (Gulf Coast Research Laboratory, 1980) and reflect the higher sea surface temperatures (evaporation is greater) and reduced rainfall and riverine input into the Sound. The lowest average salinities in Mississippi Sound (7.0-12.3 ppt) occur from March through June and reflect the high precipitation and riverine (Mobile, Pascagoula, and Biloxi Rivers) input which occur during this season. Salinities in the lagoons are probably lower than in the sound during the March through June period because of the high rainfall and generally restricted lagoonal circulation. Salinities in the lagoons are probably higher than in the Sound during the August through November period due to the lower precipitation, high evaporation, and restricted lagoonal circulation. Franks (1970) observed salinities (Table 3) of as high as 29.9 ppt and as low as 7.5 ppt in the lagoons he studied. It is difficult to determine whether or not these reflect or corroborate the above noted factors, since the data of Franks (1970) is often based on single observations of unknown dates. In addition, Franks' sampling locations within each pond and lagoon are unknown; these may also have a bearing on the result. For example, during a period of extended rainfall, the farther away from the mouth of a lagoon that the sample was taken, the lower the salinity would be.

Table 5. Mean sea surface temperature and salinity ranges for the north shore waters of Horn and Petit Bois Islands (compiled from Eleuterius and Beaugez, 1979).

Season	Temperature ^{o}F	(^{o}C)	Salinity ppt
Winter	54-59	(12-15)	17-21
Spring	70	(21)	13-18
Summer	82-84	(28-29)	19-23
Autumn	66-70	(19-21)	23-29

Natural populations of the eastern oyster, Crassostrea virginica (Gmelin), are currently present in lagoons 7 and 28 on Horn Island and lagoon 3 and pond 14 on Petit Bois Island. McGraw (1980) noted that oyster production in Mississippi has declined in recent years and attributes this primarily to hurricanes, floods, and pollution. Hase (1982) suggests that the small oyster populations on Horn Island are due to insufficient cultch (solid substrates such as shell, rock, rhizomes) material necessary for successful oyster larvae settlement. McGraw (1980) investigated the growth and survival of three oyster seed types: hatchery-reared singles, hatchery-reared attached, and wild seed oysters in five Mississippi Sound locations. Her study sites included lagoon 28 on Horn Island. The following discussion of lagoon 28 hydrography and oyster growth and mortality is based on her two year investigation.

The physical factors which have the greatest influence on oyster growth are temperature, salinity, turbidity, abundance and type of food species, and substrate type (McGraw, 1980). The water temperature affects the growth rates of northern and southern oysters. Ingle (1950), Gunter (1951), and Hopkins and others (1953) (cited in McGraw, 1980) found that oysters in the northeastern Gulf of Mexico grow throughout the year and reach market size faster than oysters found in colder, northern waters. Hayes and Menzel (1981) found that mature oysters spawn twice during the reproductive season in northern Gulf of Mexico waters as opposed to once in the colder waters along the northern Atlantic coast of the United States. Hase (1982) suggests that recruitment to the oyster population is dependent on the quantity of spawning activity in the area which determines setting potential. The salinity also influences not only oyster growth but survival. During extended periods of high river discharge and precipitation, with salinities ranging from 1-10 ppt, adult mortality can be significant. Spat set is also inhibited during such periods of low salinity. Extended periods of high salinities (greater than 32 ppt) are also detrimental to oyster growth and survival (summarized in McGraw, 1980). High turbidity reduces the pumping and thus the filtering capacity of oysters and leads to not only a reduction in growth but also in oyster quality. Oysters are dependent on the quality and concentrations of phytoplanktonic organisms for nourishment in the surrounding waters. Certain algae have been found to inhibit as well as enhance oyster growth. Excessive concentrations of plankton, in a manner similar to excessive turbidity, can also inhibit growth (summarized in McGraw, 1980). The nature of the bottom or substrate upon which the oysters grow has been shown to influence their shell growth. Gunter (1938) and Galtsoff (1964) (cited in McGraw, 1980) found that single oysters grown on hard bottoms generally produced round shells and had a high tissue production. Oysters which are crowded or which grow on soft substrates, such as those found in the ponds and lagoons of Horn and Petit Bois Islands, generally develop long, slender, thin shells.

McGraw's (1980) study of Horn Island oysters was restricted to lagoon 28, variously called Oyster Lagoon and Ranger Lagoon. Her experimental site was located in the southeast portion of the lagoon in approximately 3 ft (1 m) of water. The bottom consisted of soft mud. McGraw (1980, p. 32, 33) noted that "very few live oysters existed in the lagoon, although patches of weathered shells suggested that the population was larger in recent years. Interviews with some local fishermen revealed that the lagoon has been a favorite place to gather oysters for many years. Apparently overharvesting, along with predation, depleted the supply of oysters." Hase (1982) observed the following oyster predators in the lagoons of Horn Island: stingrays (*Dasyatis* spp.), blue crabs (*Callinectes sapidus*), black drum (*Pogonias cromis*), and oyster drills (*Thais haemastoma canaliculata*).

McGraw (1980) monitored the temperatures, salinities, chlorophyll *a* and oxygen concentrations of the waters of the southeast portion of Horn Island lagoon 28 from October 1976 through November 1977 during her oyster studies. Her results are summarized in Table 6. Chlorophyll *a* concentrations are a measure of the phytoplankton standing crop in the water column and reflect the food available to the oysters and other filter-feeding organisms.

Table 6. Hydrographic data for Horn Island lagoon 28 from October 1976 through November 1977 (from McGraw, 1980).

Parameter[1]	Minimum	Maximum	Mean	N
Temperature	8.50	32.50	23.40	14
Salinity	7.00	31.00	18.90	14
Chlorophyll a	0.18	2.60	1.43	14
Oxygen	5.90	13.50	8.10	14

[1] Temp. (^{o}C), Sal. (ppt), Chl. a (mg/M^3), O_2 (ppm).

($^{o}F = \frac{9}{5}\,^{o}C + 32$)

In addition to the above parameters, McGraw (1980) monitored the suspended sediment concentrations of the water at her five experimental sites. The results for Horn Island lagoon 28 are shown in Table 7. It should be noted that Horn Island had the highest average for the four months, 61.8 mg/L. However, no significant difference (P = 0.05) was found between the means of all sites.

Table 7. Amount of suspended material (mg/L) in Horn Island lagoon 28 from August through November 1977 (from McGraw, 1980).

August	September	October	November	Mean
10.0	121.3	87.7	28.0	61.8

McGraw (1980) also found that oysters in Horn Island lagoon 28 increased more in size than those at her other experimental stations on Cat Island, in Back Bay Biloxi, at Gulf Coast Research Laboratory, and Point Cadet. "They exhibited a mean length of 3.0 inches (7.6 cm), or market size in November 1977, one year after being placed at the site. This represented a 135% average increase in length . . . All oyster types . . . grew in excess of 4.2 cm in length during the study. Growth was significantly better at Horn Island than at other locations . . . Assessment of qualitative aspects, such as shell shape, amount of fouling, and meat texture, indicated that oysters placed at Horn Island were of high quality, such as those selected for raw (half-shell) trade" (McGraw, 1980, p. 71). McGraw (1980) determined that growth rates were "usually greatest during spring and summer months, corresponding with increases in water temperature." Maximum growth occurred between the months of June and August, but decreased during the winter months. She found no significant difference (P = 0.05) between growth rates of the hatchery and wild seed oysters at the same stations. Hase (1982) studied the relative growth rates of suspended, young oysters in lagoon 28, in Mississippi Sound, approximately 150 m (160 yd)north of the Horn Island small craft pier near the "Horseshoe," and at a location near Point Cadet, Biloxi Bay, Mississippi. He found that oysters increased in mean height (umbo to bill) by 9.7 mm (0.4 in), 13.5 mm (0.5 in), and 16.1 mm (0.6 in) in Biloxi Bay, Mississippi Sound, and lagoon 28, respectively, during the 81 day study. Mean growth rates of both lagoon 28 and Mississippi Sound oysters were significantly (P = 0.05) greater than mean rates of growth for those suspended in Biloxi Bay and averaged about 6 mm (0.2 in) per month in lagoon 28. He attributes the higher growth rates to the greater concentrations of detritus and warmer waters in lagoon 28. Although McGraw (1980) found no correlation between chlorophyll a concentrations and the high growth rates in lagoon 28, her study and those of others indicate that oysters grow faster in areas where marsh grasses are abundant. These studies collectively suggest that organic detritus, consisting of plant fragments, is of greater importance in oyster nutrition than simply phytoplankton. Lagoon 28 on Horn Island, and indeed the other oyster lagoons and ponds of Horn and Petit Bois Islands, are shallow, surrounded by abundant marsh vegetation, protected from high wind produced turbulence, and subject to high water temperatures, all of which are factors contributing to primary production.

Hase (1982) tested shells of the American oyster Crassostrea virginica and the common rangia clam Rangia cuneata, and branches of the southern wax myrtle Myrica serifera for their potential to provide oyster larvae substrate. He found that oyster spat settled preferentially on plots of oyster shells: "Differences were so great that the smallest number of spat found on any oyster-shell plot exceeded the largest number of spat sampled from any clam-shell plot" (p. 12). He also found that the wax myrtle branches were effective as a substrate for spat settlement (see Table 8). Hase suggests that there is "some residual protein" (p. 25) from the living oyster which may attract mature larvae to set preferentially on the oyster shell cultch rather than on the clam shell or wax myrtle branches. Veitch and Hidu (1971) identified a large protein from partially purified oyster shell liquor that stimulated spat-setting in the American oyster.

Hase (1982) found higher spat-setting at the mouth of lagoon 28. He suggests "that most of the larvae in the lagoon originate from the Sound via tidal exchange and not from oysters spawning in the lagoon itself. The peak

Table 8. Spat catch on three types of cultch in lagoon 28 (from Hase, 1982).

Oyster Shell		Clam Shell		Myrtle		Controls (no cultch)	
Station	No. of Spat	Station	No. of Spat	Station	No. of Spat	Station	No. of Spat
2	134	1	2	3	49	4	0
5	172	6	2	10	17	8	0
7	160	26	10	12	10	9	0
14	167	27	37	17	45	11	0
16	315	29	7	19	20	13	0
18	230	31	32	21	71	15	0
25	290	32	0	22	10	20	0
30	96	34	88	38	41	23	0
33	270	36	13	39	52	24	0
35	230	37	10	40	40	28	0
Mean	206.4		20.1		35.5		0
Standard Deviation	71.9		26.9		20.3		-

setting period observed in the lagoon corresponded with peak setting of oyster larvae off of Bellefontaine Point in Mississippi Sound north of Horn Island" (p. 28). He also points out that although annual rates of setting vary greatly, those he observed ($176/m^2$/day, $16/ft^2$/day) are high. Of greater importance, he found the number of successful spat sets on planted oyster shells to be 248 spat per 0.03 m^3 (1 ft^3) of shell planted of which approximately 6 percent can be expected to survive.

McGraw (1980) found that oyster mortality rates fluctuated seasonally and were nonsynchronous among experimental sites. Instantaneous mortality rates at Horn Island differed from those of her other four stations, with peaks in April, June, and September. The pattern of mortality appeared to be dependent more on temperature than salinity with the greatest mortalities occurring in the 20-30° C temperature range. However, the mortality was directly related to temperature and salinity. The greatest mortalities occurred during the summer when sea water temperatures and salinities were highest. The major cause of mortality was the oyster pathogen Perkinsus marinus which proliferates and is more lethal at higher temperatures and salinities.

Oyster spawning occurs in late spring or early summer and continues throughout the summer and autumn until October (McGraw, 1980). Major predators of all oyster types include mud crabs (Panopeus herbstii), blue crabs (Callinectes sapidus), and the southern oyster drill (Thais haemastoma canaliculata).

Hase (1982, p. 31) suggests two factors which are limiting oyster populations on Horn Island: "(1) lack of sufficient cultch material for setting larvae;

and (2) high mortality of young spat and older seed oysters." Gunter and Demoran (1970) attribute the general decline in oyster populations throughout the United States since 1880 to: industrial pollution, freshwater diversion, silting, overfishing or poor management, and domestic sewerage pollution. Hase (1982) suggests that because of Horn Island's location offshore, pollution and freshwater diversion are not responsible for the decline in Horn Island oyster populations, "but rather as a result of overfishing and lack of management" (p. 30). In addition, siltation would not appear to be a causal factor since human activities which might produce such conditions are not present on the island. Hase concludes that "proper management practices need to be instituted by the National Park Service to insure the continuation of adequate oyster populations in the island's lagoons" (pp. 30-32) and makes the following recommendations:

1. Regularly monitor (once every summer and winter) the size and condition of oyster populations on all islands.

2. Plant additional cultch materials (preferably oyster shells).

3. Plant adult brood oysters (taken from approved waters) to increase the yield of young oysters.

4. Replant cultch materials and/or brood oysters as determined by the monitoring program.

5. The time of cultch planting should be based on the results of spatfall monitoring.

6. The size of oysters which are taken from the lagoons should be restricted to those measuring at least 3 inches in length.

7. The amount of oysters taken by any one person in any one day should

be limited to 5 gallons of unshucked oysters or 1 pint of shucked oysters.

8. The methods of harvesting should exclude the use of dredges.

9. All oysters harvested on any island should be consumed on that island and the shucked shells should be returned to the waters of the lagoon from which they came (preferably contiguous with the shoreline)

10. Prohibit the harvesting of island oysters if the results of monitoring indicate that overharvesting has occurred. The prohibition should continue until monitoring shows that the oyster stocks have recovered to an acceptable level.

11. Seek qualified, professional advice before making any oyster management decisions such as cultch planting, brood stock planting, or closing the island to oyster harvesting.

Recommendations for Future Research

1. Determine the ecology, quality and size of all the oyster populations on not only Horn and Petit Bois Islands but also on East Ship Island.
2. Determine magnitude of visitor harvest of oysters.
3. Determine if natural recruitment in oyster populations will sustain harvest without population deterioration.
4. Investigate the hydraulic, geologic, chemical, and biotic relationships of the larger lagoons on Horn (lagoons 7, 28, 41), Petit Bois (lagoons 3, 7), and Ship Islands.
5. Investigate the hydraulic, geologic, chemical, and biotic relationships of the larger ponds on Horn (ponds 18, 20, 43, 51, 61), Petit Bois (ponds 8, 13, 14, 17), and Ship Islands.
6. Repeat the study by Franks (1970) using the same methodologies on the larger ponds and lagoons (investigated by Franks) to determine if any changes in fish population structure have occurred since his investigations of 1965 and 1966.
7. Investigate infaunal and epifaunal invertebrate populations of the ponds and lagoons.
8. Evaluate the submerged and emerged floral components of the ponds and lagoons.
9. Develop interpretive programs dealing with the geology and ecology of what are certainly the last remaining, relatively undisturbed, insular ponds and lagoons along the northeastern Gulf of Mexico coast.

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